RED MOUNTAIN, ARIZONA: A DISSECTED VOLCANIC CONE

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The location and form.—On the peripheral portion of the San Francisco Mountains, and about 30 miles northwest of the village of Flagstaff, Ariz., there is a small tuff cone, locally known by the somewhat appropriate name of Red Mountain. This cone bears the name of Mesa Butte on the San Francisco Mountain sheet of the topographic atlas. It rises between 700 and 800 feet above the general level of the plateau on which it stands, and at the summit is at least 7,750 feet above sea-level (Fig. 1).

When approached from the southeast or northwest, Red Mountain presents an even, dome-shaped form, such as is common to many of the cinder cones of the region, and if seen from either of these directions it would not attract special attention. On the southwest side a valley has developed, and the material taken from the mountain has been spread out at the base as an alluvial fan. On the northeast side there is a unique exposure, where the mountain has been so cut open that its internal structure is beautifully shown. From a distance (Fig. 2) few details of the exposure can be made out, but a number of layers appear which are roughly concentric and approximately parallel to the profile of the mountain. At closer range (Fig. 3) the concentric layers come out more strongly and they are seen to decline, not only to the right and left, but also toward the observer.

The material.—The material of Red Mountain consists of volcanic dust, cinders, lapilli, small crystals and fragments of crystals, a few bombs, many angular blocks, some agglomerate, and a bed of lava which is in part scoriaceous and in part compact. By far the greater amount of the material consists of the smaller products of volcanic eruption. About the base of the mountain, and high on the slopes, there are large quantities of black cinders and lapilli. They

were a relatively late contribution to the cone, and are unconsolidated. Within the mountain the fragmental material is cemented into a typical volcanic tuff. When seen from a distance, the color of

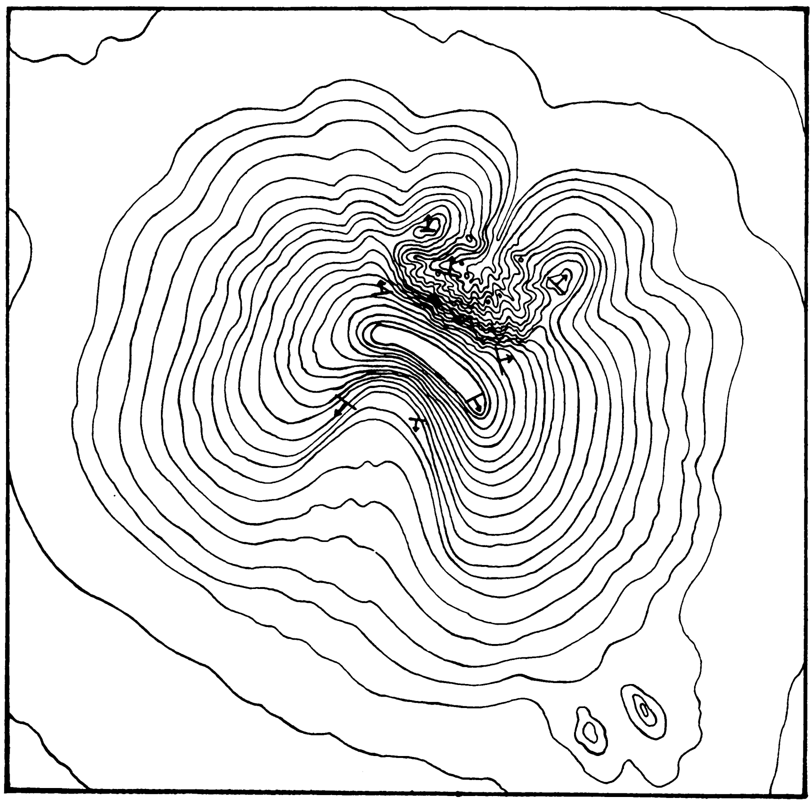

FIG. 1.—A topographic sketch of Red Mountain, Arizona, with the directions of dip and strike plotted at several points.

the tuff resembles that of the red beds, but at close range it is seen to be a combination of yellows and browns.

The angular blocks, which range up to 4 feet in diameter, are composed of a dark-red porphyritic andesite. The phenocrysts are labradorite feldspars, pyroxenes, hornblendes, and magnetites. The lava flow and agglomerate are exposed only on the southwest side of the mountain, about 100 feet below the summit. The largest out-crop shows a zone, 10 feet thick, of compact lava in which there

is a distinct flow-structure, between scoriaceous zones. The scoriaceous zone at the base is at least 5 feet thick, and that at the top is about 10 feet thick. At another exposure, 6 feet of compact lava overlie a scoriaceous zone 10 feet thick. Imbedded in the scoriaceous zone, at the base, there are huge blocks of compact lava. Both the scoriaceous and compact portions are porphyritic. The exposures of agglomerate are near the layer of lava, and associated with the surface of the flow.

Small crystals and fragments of crystals are exceedingly common in the tuff. Probably there is not a square foot on the surface of the tuff, as now exposed, where crystals could not be found. The chief minerals represented are plagioclase feldspars, pyroxenes, and hornblendes. The plagioclases have characteristic striations, they are clear and glassy, and range up to an inch in diameter. The pyroxenes and hornblendes are commonly jet-black, and vary in size up to three-fourths of an inch. The crystals are a part of the fragmental material ejected by the volcano, and were therefore formed in the magma before eruption. The formation of these crystals, as well as those in the angular blocks and in the lava flow, caused an increase in the gaseous pressure in the magma, and according to the suggestion of Chamberlin and Salisbury, may have been an important factor in causing the explosions.[1]

The gases occluded in the andesite and in the pyroxene crystals have been determined by R. T. Chamberlin. One volume of the rock gave 6.37 volumes of gas of the following composition:

H_2S	0.01
CO_2	80.38
CO	9.02
CH_4	4.72
H_2	1.84
N_2	4.00
	99.97

One volume of the crystals gave 1.11 volumes of gas of the following composition:

[1] Chamberlin and Salisbury, *Text-book on Geology*, Vol. I, p. 618.

H_2S	8.90
CO_2	62.62
CO	14.46
CH_4	1.30
H_2	7.01
N_2	5.71
	100.00

The structure.—The San Francisco Mountains and associated cones rest on the Colorado plateau, where Carboniferous limestones

FIG. 2.—General view of Red Mountain from the northeast.

appear at the surface. According to Dutton, the plateau was not reduced to the Carboniferous horizon until late in Miocene times.[2] The writer has reported evidence of Pleistocene glaciation in the main crater of the San Francisco Mountain,[3] and it is fair to assume that volcanic activities had ceased in the entire region by that time. The geologic age of these mountains is therefore probably late Tertiary. The cone under consideration appears to rest, in part at least, upon a lava flow that issued from the main crater or from

[2] Dutton, *Tertiary History of the Grand Canyon District*, Monograph II, U. S. Geological Survey, p. 221.

[3] "Glaciation of San Francisco Mountain, Arizona," *Journal of Geology*, Vol. XIII (1905), p. 276.

some fissure associated with the center of activities. This relationship indicates that Red Mountain was developed during the later, rather than during the earlier, phases of vulcanism in the region.

The general position of the layers of tuff has been referred to, and the directions of the strike and dip have been plotted at several points on the topographic sketch (Fig 1). The layers near the base, and as

FIG. 3.—Northeast side of Red Mountain, showing structure.

near the center of the mountain as it is possible to get, decline 4°. They are, probably, some of the ealiest deposits made about this vent. As the fragmental material accumulated, it formed steeper and steeper slopes about the rim of the crater, and today the exposures show an increasing dip from the base to the summit, passing gradually through angles of 5°, 10°, 15°, up to 20°. The major divisions in the tuff appear, from a distance, to be from 15 to 20 feet thick. On closer examination subdivisions may be recognized down to an average thickness of from one to two inches. Within a layer or bed of tuff there is no noticeable assortment of material.

Each explosion added a thin coating of fragments that were intimately intermingled in the air before falling to the mountain slopes.

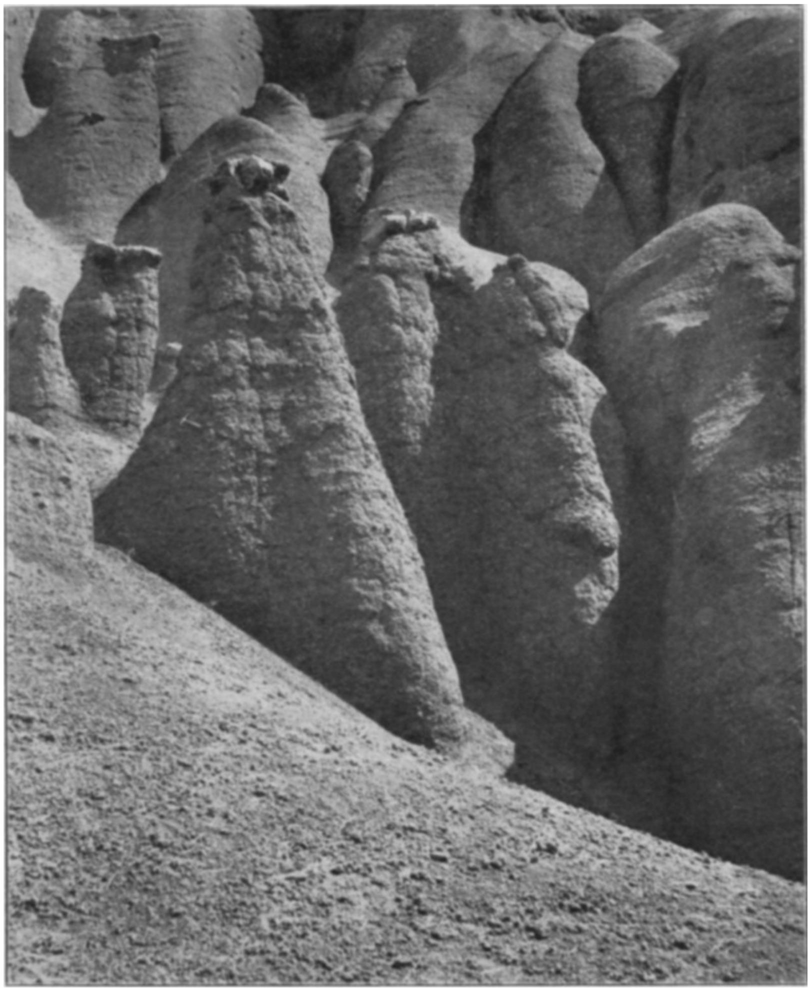

FIG. 4.—Close range view in Red Mountain, showing pillars of volcanic tuff capped by angular blocks of lava.

At very close range (Fig. 4) the surface of the tuff appears rough and the bedding is indistinct. Certain explosions contributed large quantities of angular blocks which now characterize different

horizons. In general, the contributions of angular blocks were greater during the later than during the earlier eruptions. At times true volcanic bombs were thrown out, which indicate that molten lava must have risen well up into the crater.

The lava which issued near the close of the period of growth overflowed to the southwest and descended but part way down the slope.

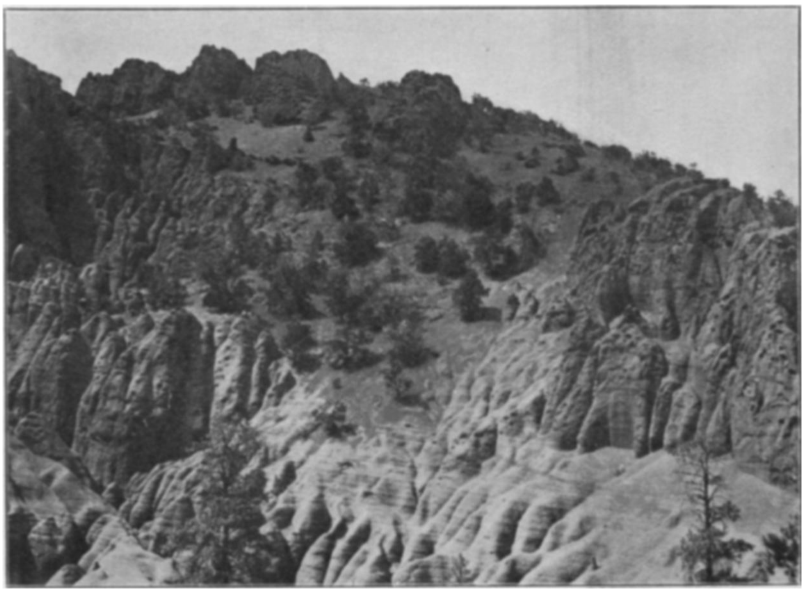

FIG. 5.—Looking west in Red Mountain. The layers of tuff come out clearly near the base, but are obscured on the upper portions of the slope by the general pitted condition of the surface. The pits are where great masses of lava have been weathered out.

The southwest portion of the crater rim was presumably lower most of the time, for the prevailing winds from that direction must have carried a large proportion of the ejected material to the northeast side.

The erosion.—Rain and running water have removed all traces of the crater, and the present summit is but a narrow crescentic ridge dividing the waters which operate on the southwest and northeast slopes. The erosion on the southwest side has been referred to with sufficient detail. On the northeast the mountain may be

entered through a narrow gorge. This gorge is not commonly occupied by a stream, but its form is such as to indicate that it was made by running water. Within the gateway the excavation in the mountain broadens out into an open amphitheatral form, and serves as an immense funnel concentrating the waters which fall on that side of the mountain.

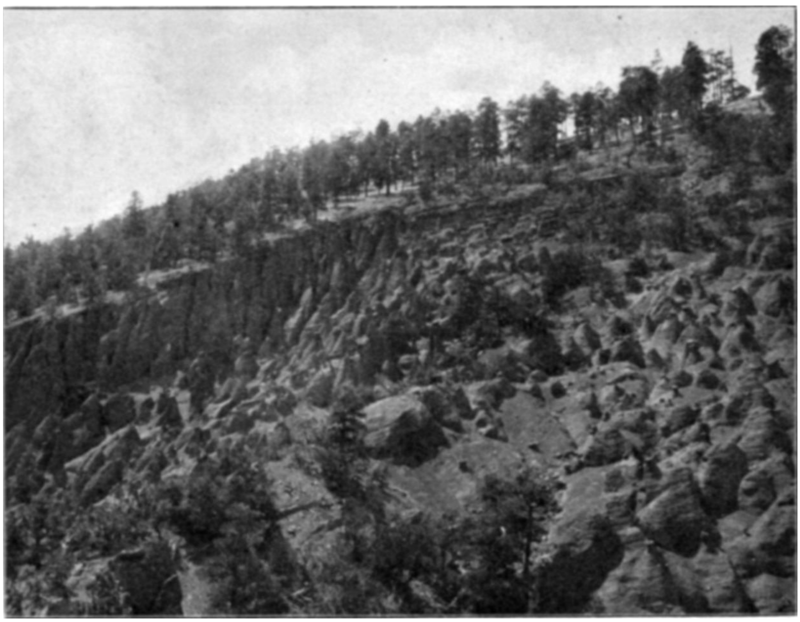

FIG. 6.—Looking east in Red Mountain, showing numerous pillars and mounds which have resulted chiefly from rain erosion.

The erosion-forms in the amphitheater resemble those common to bad lands. There are narrow winding passageways which end as box canyons; on projecting spurs there are sharp pinnacle-like forms capped with angular lava blocks; the walls are decorated with strangely irregular forms, and marked by great pits where large masses of lava have been weathered out. To the west (Fig. 5), the layers come out clearly near the base, but higher on the slopes they are indistinct. To the east there are numerous pillars and mounds in various stages of development (Figs. 4 and 6). Some of the pillars are just being separated from the main mass of the moun-

tain. Others have become isolated and stand 5–15 feet above their surroundings. Some appear to have recently lost their capstones and stand as unprotected spires. Others have long since lost the protection offered by the blocks that caused their development, and are now reduced to mounds. In portions of this area these mounds resemble an irregular grouping of old-fashioned bee-hives. The work of erosion goes on very slowly now, but may be assumed to have been more rapid during the moist climate of Pleistocene times.

A summary.—Based on the above data the history of Red Mountain may be sketched as follows: Late in the Tertiary period a secondary volcanic vent opened on the outskirts of the San Francisco Mountain center. A series of explosions occurred, building up a cone of fragmental material to a height of several hundred feet. The first material ejected fell on a relatively flat surface. As the cone grew in size, the fragmental material rested at higher and higher angles. Lavas rose into the crater, and volcanic bombs were formed. The winds carried much of the loose material to the northeast, building that portion of the crater rim highest. Late in the growth of the mountain a small amount of lava issued from the crater and flowed part way down to the southwest slope. Eruptions continued until the mountain rose about 1,000 feet above the plateau level. Based on the number of layers in the tuff, a conservative estimate of the number of explosions necessary to have built the cone is between 4,000 and 5,000. This estimate does not allow for any height above the present summit, and is therefore probably far below the correct figure.

Waters that were presumably associated with each eruption and more recent rains assisted in cementing the fragmental material together. Rain and running water have now partially dissected the cone, exposing the successive layers of fragmental products and developing a large variety of peculiar forms. The remarkable exposure on the northeast side extends nearly to the core of the mountain.